

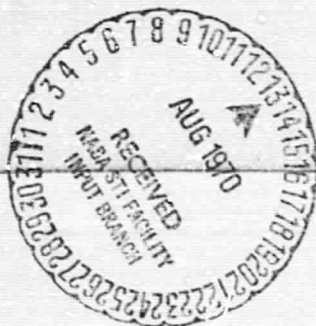
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S-IVB/V AUXILIARY PROPULSION  
SYSTEM 90-DAY RECYCLE  
CAPABILITY TEST REPORT,  
MODULE III  
SUPPLEMENT I



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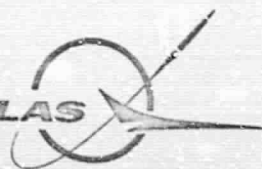
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**S-IVB/V AUXILIARY PROPULSION  
SYSTEM 90-DAY RECYCLE  
CAPABILITY TEST REPORT,  
MODULE III  
SUPPLEMENT I**

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SATURN/APOLLO & APOLLO APPLICATIONS PROGRAMS

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PREPARED FOR:  
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UNDER NASA CONTRACT NAS7-101  
MODEL DSV-4B

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## PREFACE

This supplement documents the bladder vendor's (Bell Aerosystems Company) failure analysis on the defective bladder found in Module II. This analysis was documented by Bell Aerosystems Company report number 8400-928017, dated May 12, 1969.

This supplement, prepared under National Aeronautics and Space Administration Contract NAS7-101 (Change Orders 1671 and 1987), is issued in accordance with line item FQ-L-70.



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## 1. INTRODUCTION

The defective bladder (P/N 8339-471080-3, S/N 136-3) and its diffuser tube (P/N 8400-471004-3, S/N 38) were received at Bell Aerosystems Company (BAC) in February 1969, with McDonnell Douglas Astronautics Company's (MDAC) failure documentation.

The bladder had been disassembled from its diffuser tube by MDAC, and photos of the retainer-cone to diffuser-tube weld were taken. The photos show a highly magnified profile and in-plane view of the weld bead tailoff area where there was a very small, rounded, black projection proposed to be the cause of the bladder failure, presumably from puncture. (Reference figures 6-9 through 6-15, Report No. DAC-56729, S-IVB/V APS 90-Day Recycle Capability Test Report, Module II.)

The failure analysis described in the following paragraphs was initiated in March 1969.

## 2. FAILURE ANALYSIS PROCEDURE

The evaluation plan for the bladder failure analysis was directed along three parallel, concurrent efforts. They are as follows:

- a. Bladder failure examination.
- b. Diffuser tube weld examination.
- c. Failure mode reproduction testing.

The bladder examination included macroscopic and microscopic visual examination, photographs, and microtomed sections across the failure area. From these studies, and a comprehensive background of several past bladder failure and study analyses, the failure mechanism and probable cause were determined.

The diffuser tube weld was examined, X-rayed, and the suspect area photographed under magnification.

The implication that a weld projection punctured the bladder was not deemed likely by BAC after hardware examination; however, proof of the BAC hypothesis was sought by testing an existing Model 8400 bladder assembly in a plexiglas tank shell. The bladder was marked circumferentially at the failure distance from the retainer end. The bladder was



then loaded with Freon-TF and ullage was drawn in six incremental steps at values supplied by MDAC. Photographs of the bladder at these stages of collapse were taken to show the failure zone position relative to the weld in question, and are contained in figures 2-1 through 2-6. This effort was then coordinated into a single analysis and is summarized in this report.

### 3. FAILURE ANALYSIS RESULTS

#### 3.1 Bladder Failure Examination

The defective bladder was visually examined under magnification and photographed as required prior to removal and sectioning. Measurement showed the failure to be 4.5 inches from the centerline of the tapped hole in the retainer cone and .048 inch in length. Figures 3-1 and 3-2 show the failure location and closeup exterior view in quadrant III, retainer end.

The failure area was then cut from the bladder, mounted, and then sectioned by microtoming. Figures 3-3 through 3-7 show pertinent photomicrographs of the failure section, which are discussed in detail in section 4 of this report.

The microscopic examination of the failure showed delamination and birefringent stress lines, which are attributable to fatigue type rather than mechanical puncture type bladder failures.

Figures 3-8 through 3-12 show the general bladder condition to be good with normal creasing found after expulsion and vibration testing.

#### 3.2 Diffuser Tube Weld Examination

Radiographic inspection of this suspect weld showed no evidence of the projection, voids, inclusions, or other possible bladder failure producing characteristics.

Magnified visual inspection showed the projection on the MDAC photos was gone. Figures 3-13 and 3-14 show that an irregular shaped depression existed where the projection was formerly located. However, tool marks or other evidence of how the projection "core" may have been removed are not discernible.

The "loss" of the projection cannot be accounted for. It occurred, however, before receipt of the hardware by BAC.

### 3.3 Failure Mode Testing

The Model 8400 Plexiglas Test Tank with bladder (P/N 8400-471080-3, S/N 123-3) was used to demonstrate that the failure zone was not the point of contact with the diffuser tube to retainer cone weld. The bladder was circumferentially marked 4.5 inches from the retainer nut center.

The bladder was expanded and fully loaded with 233 lbm of Freon-TF in the standard loading manner. Initial ullage of 130 cu in. (7.45 lbm) was drawn and photographs of the bladder were taken with back lighting to show the diffuser tube outline and the bladder collapse folding pattern.

Successive ullage levels were drawn to values specified by MDAC and photos were taken to show bladder/tube weld contact. Figures 2-1 through 2-6 show the bladder-tube relative positions at 130, 200, 268, 330, 450, and 600 cubic inch levels, respectively. Photos were taken at a closer view (figures 2-4 through 2-6) in order to show greater detail.

The bladder was then fully drained, decontaminated, and the test tank assembly placed in dry storage.

## 4. DISCUSSION

### 4.1 General

The test history of the defective bladder during service at MDAC is not known in detail. It appears that it was used in system vibration testing with a fuel propellant load. The detailed test levels, duration, and failure detection method are not known. The failure analysis, therefore, makes no assumptions based upon hardware testing.

### 4.2 Bladder Failure Examination

Figures 4-1 and 4-2 show the bladder failure at a magnification of 32X from the outer (tetrafluoroethylene [FEP]) and inner (a copolymer of FEP and hexafluoropropene [TFE]) sides of the bladder, respectively.



The FEP/TFE delamination is obvious and is characteristic of repetitive rolling fold failures which is correlated by the white striated appearance of the TFE surrounding the failure area. Polarized light observations revealed the birefringent properties indicative of localized stress in the immediate failure area. Since there was no rolling fold stress line leading up to the rupture, it is evident that the fold movement was very limited. (Color photos are on file at BAC showing true color birefringence. They are not included here because of reproduction costs.)

Figure 3-3 shows a section of the outer failure edge showing stress caused by a buckle or fold with resulting initiation of delamination.

Figure 3-4 shows the initial area of FEP (outer layer) rupture with the TFE (inner layer) still intact. From the TFE edge it is evident that the buckling action imparted a localized twist, and delamination increased in the failure area.

These four figures tend to discount the puncture theory, since delamination and stress bands are not characteristic of punctures. Also, the rupture of just the FEP outer layer at both ends of the failure with an intact TFE inner layer discounts an internally generated puncture, even if it were on a plane askew to the sectioning plane shown in the photomicrographs.

Figure 3-5 shows the section immediately adjacent to the total breakthrough. Localized twist has increased and the TFE is cracked at the end of the delaminated zone. The absence of "necking down" in the TFE layer is typical of rolling fold action in MMH propellant found in repetitive rolling fold tests conducted in laboratory testing on another program by BAC.

Figure 3-6 shows the matching total failure microtome sections. The TFE layer failure is abrupt with little thickness reduction and is not aligned with the FEP layer failure. These are the typical characteristics of a break usually associated with stress in either fuel or at low temperature.

Thickness measurements of the failure adjacent region were made with the following values obtained:

FEP layer	.00314
TFE layer	<u>.00302</u>
Total	.00616 inch

#### 4.3 Failure Mode Testing

The bladder folding sequence shown at various withdrawn ullage levels in figures 2-1 through 2-6 prove definitely that the bladder failed zone and diffuser contact is well below the suspect tube to retainer cone weld bead. Measurement shows failure line contact to be approximately two inches below the weld bead. Even though the dynamics tests performed on the unit are not known, it is considered extremely remote that any inputs would cause vertical bladder motion two inches in amplitude and that if such bladder movement amplitude did occur, the liquid in motion would effectively insulate the bladder material from direct diffuser tube metal contact in this area.

The sequence of collapse at ullages of 130, 200, 268, 330, 450, and 600 cubic inch levels shown in figures 2-1 through 2-6 are self-explanatory and the relative failure/weld positions are clearly discernible.

#### 5. CONCLUSIONS AND SUMMARY

The following conclusions summarize the results of the failure analysis:

- a. No discrepancy in the diffuser tube to retainer cone weld was found either by radiographic or magnified visual inspection methods.
- b. Bladder collapse at six specified stages showed the failure zone, which was 4.5 inches below retainer hole center, to be well below the suspect weld. Bladder to weld contact occurred at approximately 2.5 inches and, therefore, the proposed puncture theory by a weld bead projection is geometrically not feasible.

Physical examination of the actual bladder failure yields the following conclusions:

- a. Bladder (S/N 136-3) failure was not due to mechanical puncture or abrasion but was due to repetitive rolling of a buckled fold in a very restricted, localized area.
- b. The repetitive rolling of the buckled fold occurred during vibration testing most likely while loaded with fuel.
- c. This failure is nearly identical in location and appearance to failures noted in Model 8400 Fuel Bladder (S/N 80-3) which were caused by repetitive rolling of a buckled fold during vibration testing with MMH at Wyle Labs. (Reference BAC Report No. 8460-133012, March 1967.)

MDAC-WD is of the opinion that the bladder failure which occurred on Module II resulted from fatigue due to the vibration cycling of folds in the bladder. The number of vibration cycles required to produce a failure exceeds any expected service life of the APS and therefore will not result in a bladder failure. The small bladder holes which occurred as a result of exceeding the expected service life vibration cycling requirement did not produce a leakage rate which would affect the APS mission.



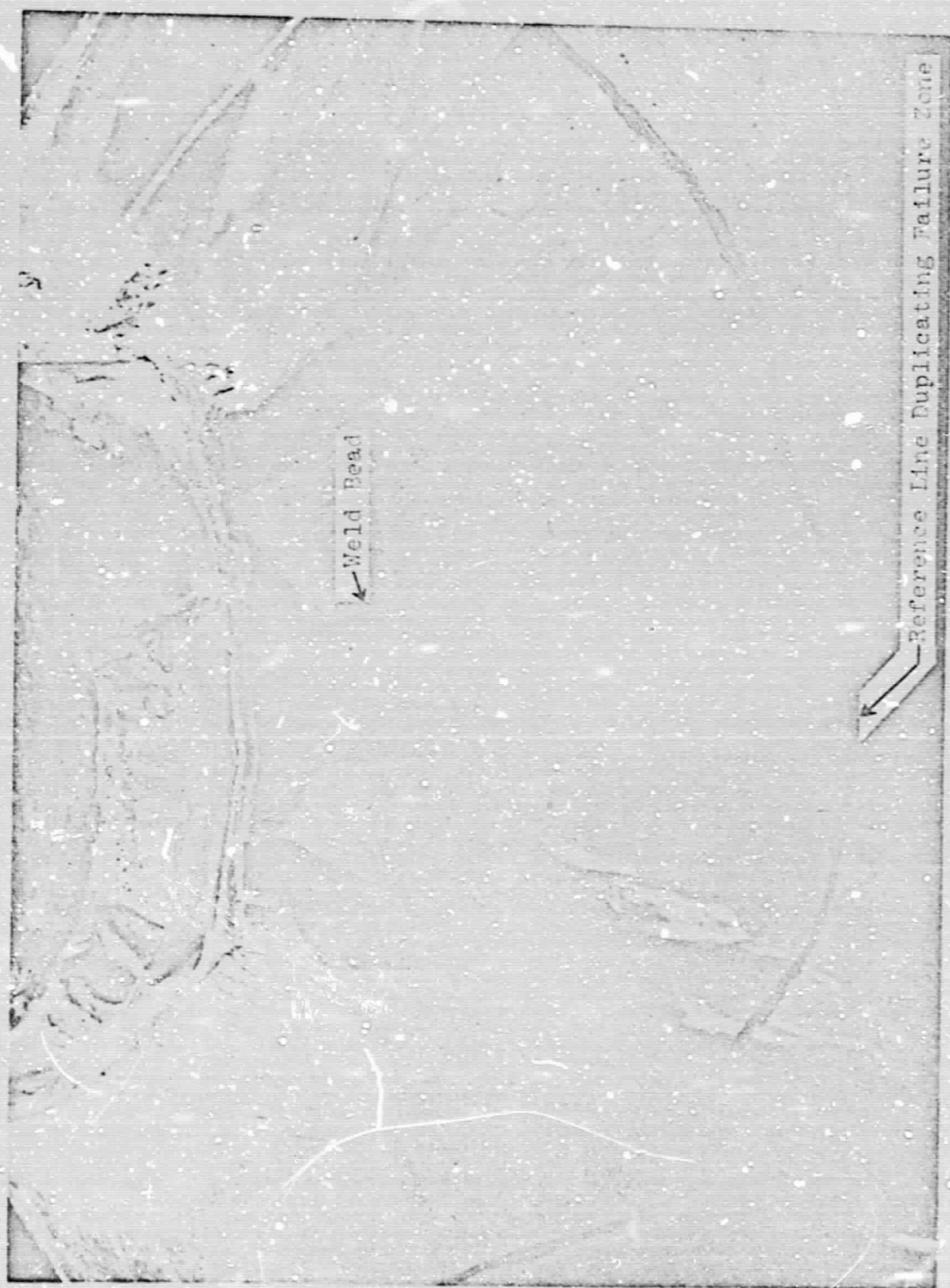


Figure 2-1 130 Cubic Inch Ullage Level



Figure 2-2 200 Cubic Inch Ullage Level



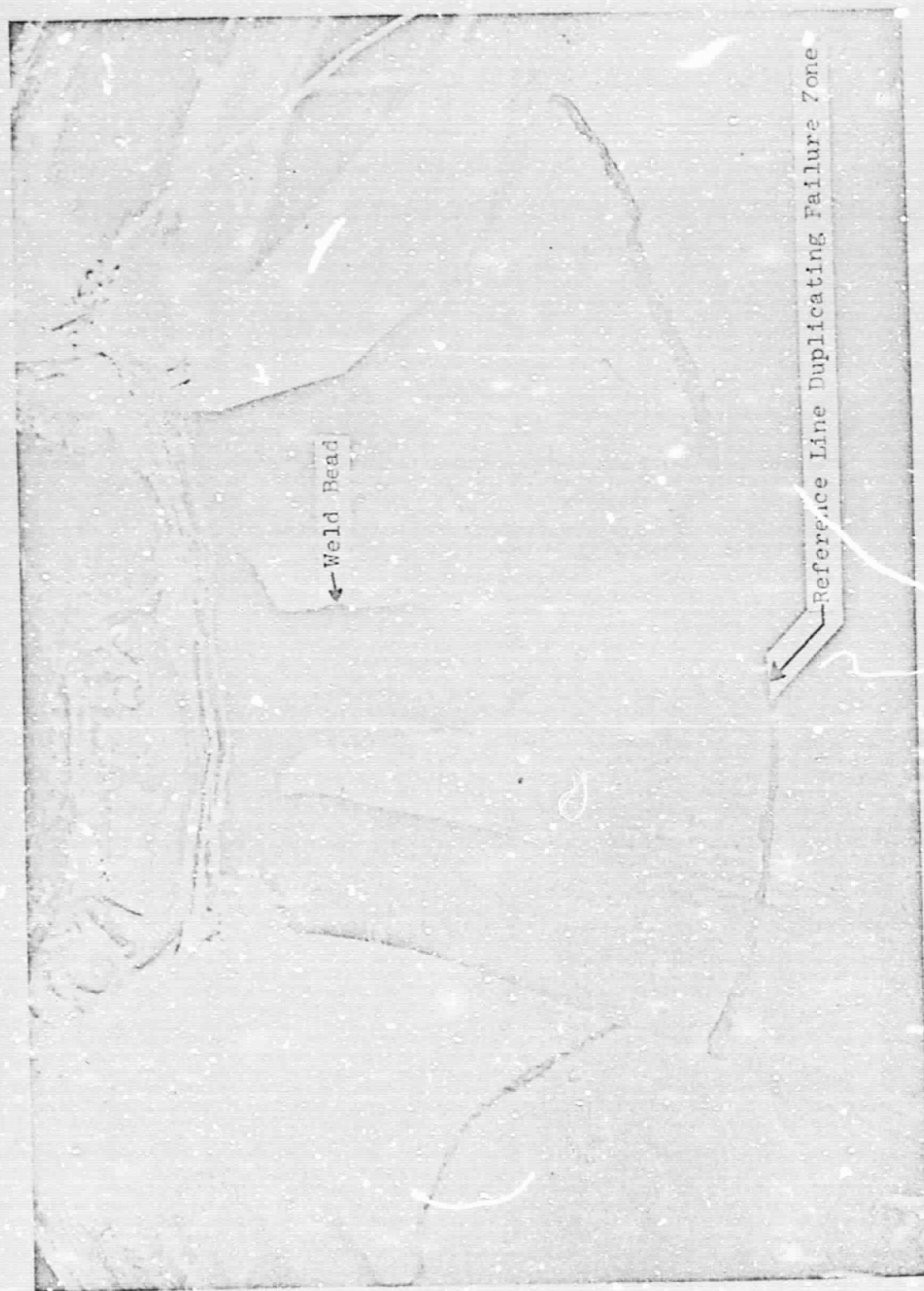


Figure 2-3 268 Cubic Inch Ullage Level



Figure 2-4 330 Cubic Inch Ullage Level

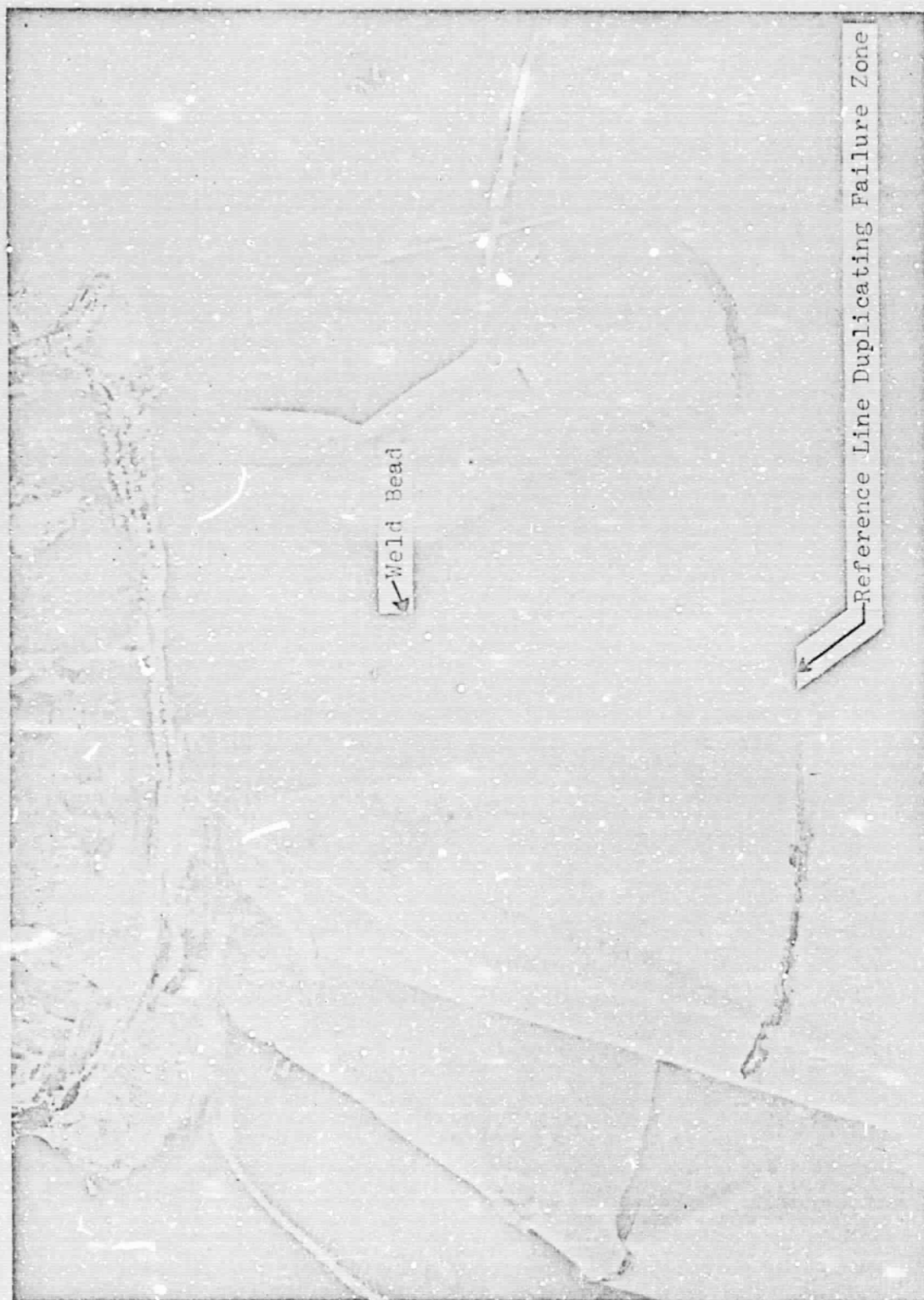


Figure 2-5 450 Cubic Inch Ullage Level





Figure 2-6 600 Cubic Inch Ullage Level

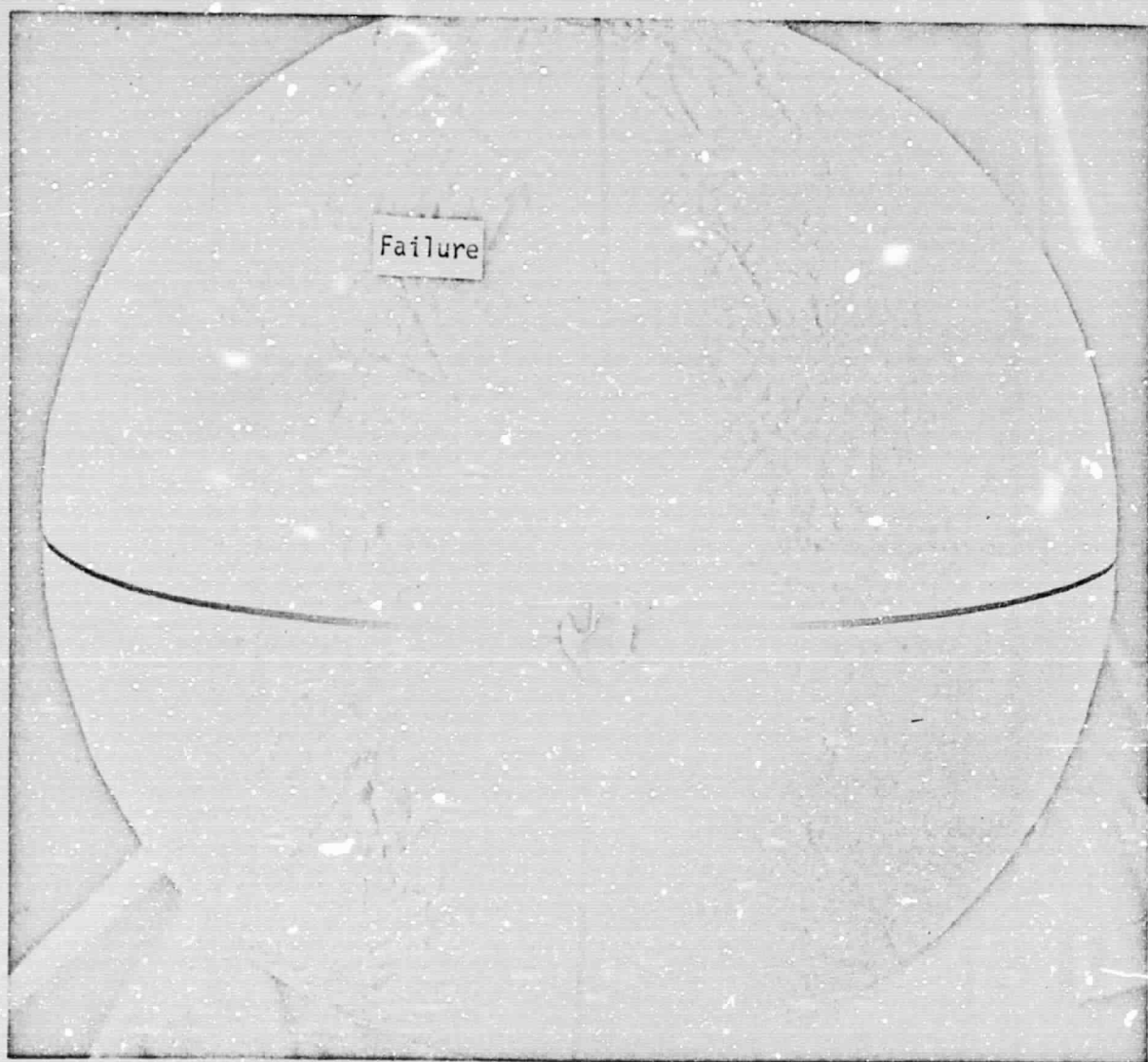


Figure 3-1 Retainer End of Bladder SII 136-3



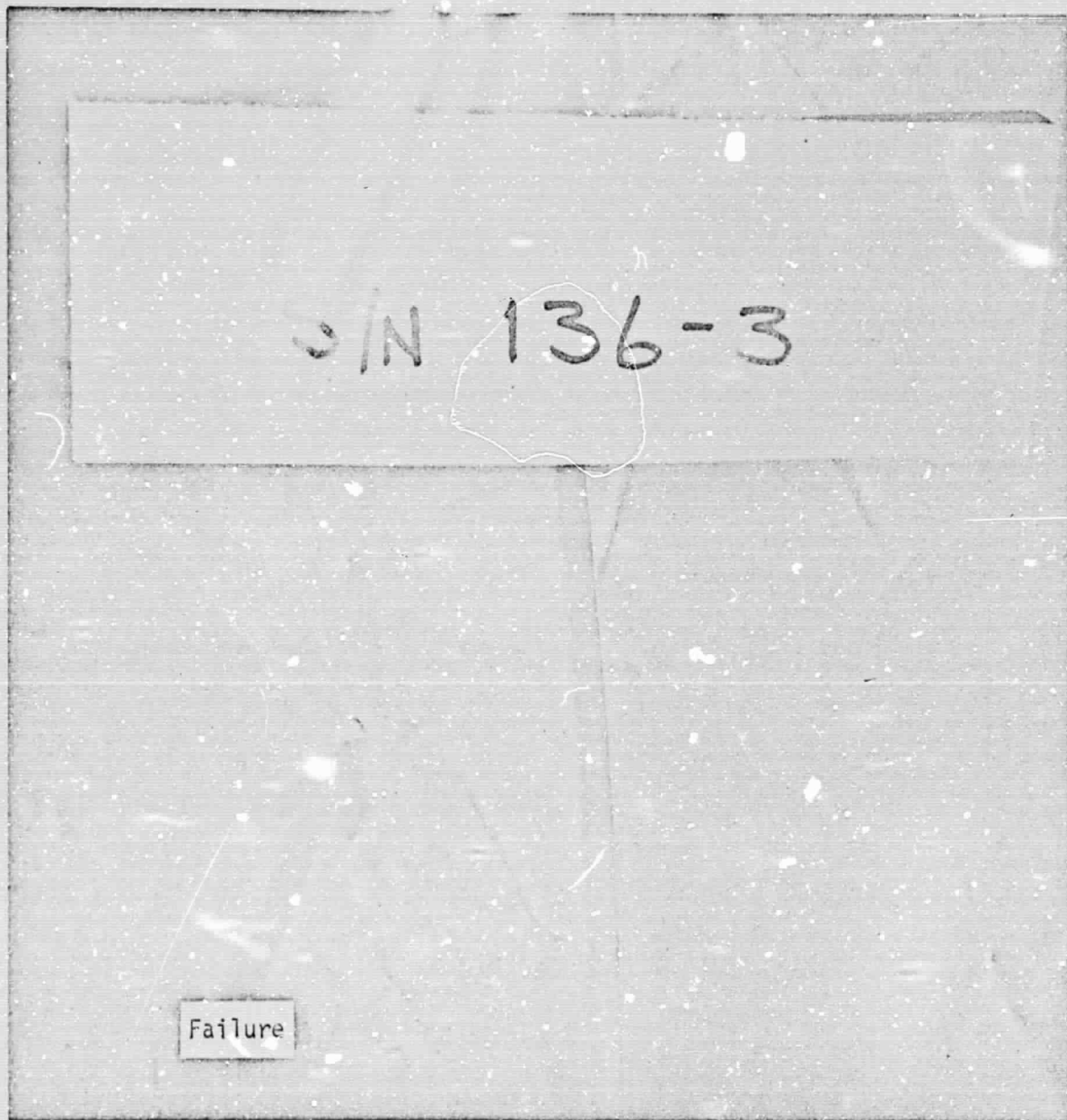


Figure 3-2 Enlarged Section of Retainer End

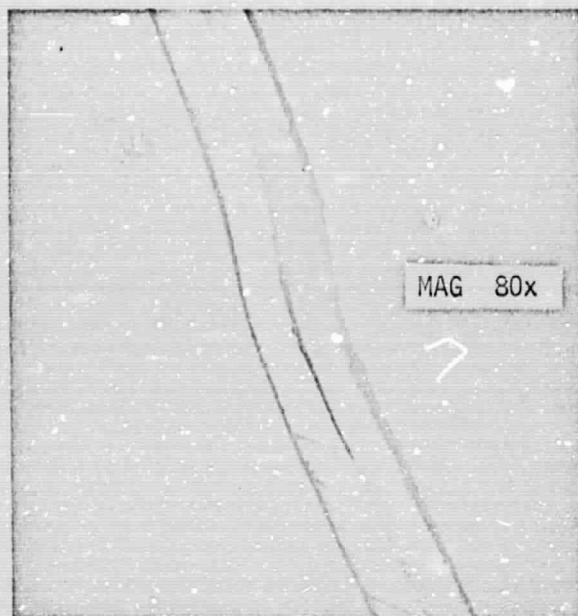


Figure 3-3 Microtome Section Through Outer Edge of Failure Area (TFE Layer is on the right)

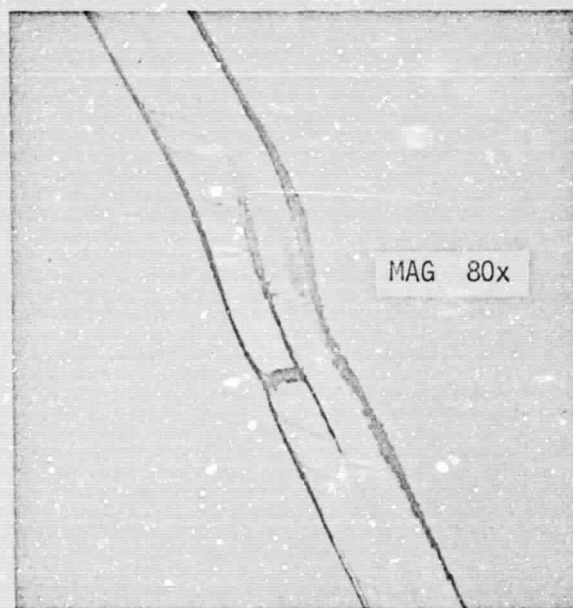


Figure 3-4 Microtome Section through Initial Area of FEP Rupture (TFE Layer is on the right)



Figure 3-5 Microtome Section through Area Immediately Adjacent to Total Rupture (TFE Layer is on the right)





(Separate Views are shown of latching Sections of Failure. Note Extensive Delamination and Shear Appearance of TFE Break. TFE Layer on left in each photo.)

Figure 3-6 Microtome Section through Ruptured Area of S/N 136-3



Figure 3-7 Microtome Section through Initial Area of FEP Rupture. (This area is at opposite end from area shown in Figure 5. TFE Layer is on the right.)





Figure 3-8 Flange End of Bladder SN 136-3



Figure 3-9 Quadrant I of Bladder SW 130-3



Figure 3-10 Quadrant II of Bladder SN 136-3



Figure 3-11 Quadrant IiI of Bladder SII 136-3





Figure 3-12 Quadrant IV of Bladder SN 136-3

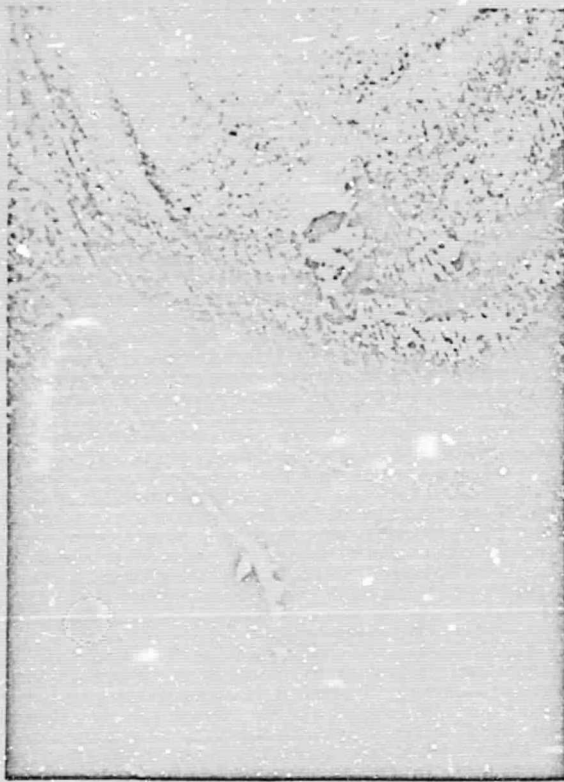


Figure 3-13

Diffuser Tube  
Weld Showing Weld Tail-Off  
Area and Location of Vacated  
Weld Bead Projection



Figure 3-14

Profile View of Weld  
Tail-Off Area and Location of  
Vacated Weld Bead Projection

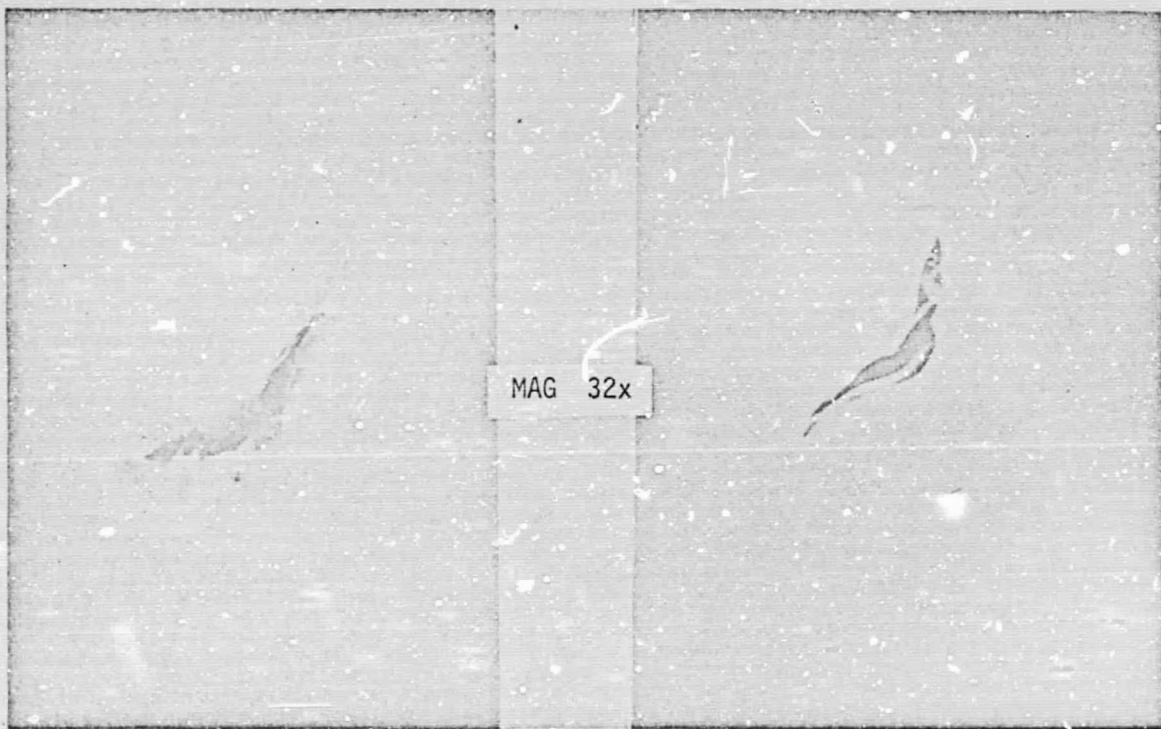


Figure 4-1 FEP View of Failure  
in Bladder SN 136-3

Figure 4-2 TFE View of Failure  
in Bladder SN 136-3